How Do You Take Your Tea? Make a Simple Electronic Device to Measure the Strength of Tea

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Abstract

A nice hot cup of tea sure can wake and warm you up in the morning. In this science fair project, you will investigate the chemistry of tea. The longer you steep a tea bag in hot water, the stronger the tea will be. But how does the strength of the tea change with longer brewing time? In this food science project, you will make a very simple electronic device to measure the strength of tea. The device will determine how strong the tea is by measuring the amount of light the tea absorbs.

Objective

Determine how brewing time affects the strength of tea, using a simple homemade electronic device that measures light absorption.

Introduction

Cooking and chemistry have a lot in common. When you make a cup of tea, for example, you are performing a sort of **chemical extraction.** In chemical terms, the tea is an **infusion.** The hot water becomes dark, due to the presence of water-soluble chemicals that are extracted from the tea leaves. The concentration of the extracted chemicals depends on the temperature of the water and how long the tea is soaked in the water. The more water-soluble chemicals there are in the water, the stronger the tea is. But *how* does the strength of the tea change with brewing time? Is tea that has brewed for 4 minutes twice as strong as tea that has brewed for 2 minutes, or is it some other strength? The goal of this science fair project is to collect data on how the strength of the tea depends on the brewing time.

To measure how strong the tea is, you will make a very simple device to measure the ability of tea to block light. The device consists of a plastic cup, a **multimeter,** and a **photoresistor.** A multimeter is used to provide a numerical output of the resistance. The photoresistor has special properties that change, depending on the level of light, and the multimeter translates those changes into numbers. More specifically, a photoresistor is a special kind of **resistor;** it is a resistor that is sensitive to light. A resistor is an electronic component that "resists" the flow of electricity. Resistors come in various shapes and sizes, but each one is able to resist the flow of electrons. The unit for resistance is the **ohm (Ω).** The larger the number of ohms, the greater the resistance. A 1,000-ohm resistor, for example, will block half as much current as a 2,000-ohm resistor. A photoresistor typically contains **cadmium sulfide.** The cadmium sulfide in the resistor responds to light by becoming more **conductive.** When the cadmium sulfide becomes more conductive, the resistance of the photoresistor decreases.

In the dark, the photoresistor almost completely blocks the flow of electricity. When the photoresistor is in the light, its ability to block the flow of electricity decreases. The resistance of the photoresistor decreases in **proportion** to the amount of light to which it is exposed. Another way to say this is that the resistance increases in proportion to the amount of light that is blocked. Since the amount of light that is blocked depends on the strength of the tea, the resistance is proportional to the strength of the tea. Let's get started!

Terms, Concepts, and Questions to Start Background Research

- Chemical extraction
- Infusion
- Multimeter
- Photoresistor
- Resistor
- Ohm (Ω)
- Cadmium sulfide
- Conductive
- Proportion
- Short (electrical)
- Negative control
- Range

Questions

- Which chemicals are responsible for the color of tea?
- What are some common items that use photoresistors?

Bibliography

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Project Summary

Difficulty	6 – 7
Time required	Average (about one week)
Prerequisites	None
Material Availability	Readily available
Cost	Average ($50 - $100)
Safety	Adult supervision is required when boiling water.

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Materials and Equipment

- Plastic cups, clear, 12-oz. (6)
- Aluminum foil
- Permanent marker
- Photoresistor, CdS (5-pack); available online from www.radioshack.com, catalog #: 276-1657
- Electrical tape
- Lamp or other source of light
- Mugs (5)
- Masking tape
- Measuring cup, liquid, metric
- Teapot or cooking pot
- Tea bags (12); use a dark tea, such as Darjeeling or Assam.
- Stopwatch or timer with second hand
- Jumper leads, 14-inch insulated test/jumper leads; available online from www.radioshack.com, catalog #: 278-1156
- Multimeter that reads resistance, such as the Equus 3320 Auto-Ranging Digital Multimeter; available online from www.amazon.com
- Lab notebook
- Graph paper

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Experimental Procedure

Making Your Light-measuring Device

1. Wrap the sides of one of the plastic cups with aluminum foil. Leave the bottom uncovered. Label it *Plastic cup #1* with the permanent marker.
2. Secure the aluminum foil with electrical tape. Use a minimal amount of tape to hold the aluminum foil in place.
3. Bend the wires on the photoresistor, where they are attached.
4. Tape the photoresistor under the cup, described as follows, and shown in Figure 1.
   a. First cover the foil with electrical tape so that the metal wires from the photoresistor do not touch any foil (Figure 1.A.). The foil would cause a **short** in the photoresistor.
   b. The part with the squiggly line should face into the cup. See Figure 1.C.

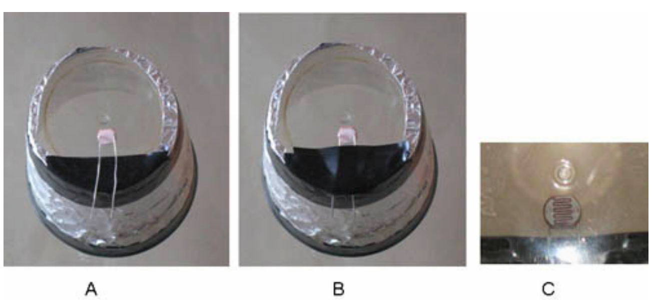

Figure 1. A photoresistor is taped to the bottom of a clear plastic cup covered with aluminum foil. The metal leads from the photoresistor are protected from the foil with electrical tape (1.A.). The photoresistor is taped in place with electrical tape (1.B.). The whole bottom of the cup is covered with electrical tape to hold the photoresistor in place and to block stray light (not shown). The cup is turned over and taped to a waterproof counter. The squiggly surface of the photoresistor (the light-sensitive side) faces the inside of the cup (1.C.).

5. Tape the photoresistor in place with electrical tape. (Figure 1.B). If there is a dot or other obstruction in the middle of the bottom, locate the face of the photoresistor away from the obstruction.
6. Now cover the entire bottom of the cup with electrical tape. This will hold the photoresistor in place and block stray light.
7. Turn the cup right-side up.

8. You will place the second plastic cup inside the cup with the photoresistor. *Don't* pour liquid into the cup with the photoresistor attached.
9. Use electrical tape to secure the cup with the photoresistor to a kitchen counter surface. The surface should be waterproof.
10. Place a lamp on the counter so that the light shines into the cup. If the cup can be illuminated with other kinds of existing light in the room instead, such as track lighting, that is fine, too.
11. It is very important that the light source stays the same for all of the tests. Once you start a series of tests, do not move the lamp or change its brightness or position.

Making the Tea

1. Label five mugs 1–5 with the masking tape and permanent marker.
2. The five mugs will hold the following samples:
   - Mug #1: Water only
   - Mug #2: Tea, 10-seconds (sec.) brewing time
   - Mug #3: Tea, 30-sec. brewing time
   - Mug #4: Tea, 90-sec. brewing time
   - Mug #5: Tea, 270-sec. (4 1/2 minutes) brewing time
3. Heat water to boiling in a teapot. The temperature of the water should be the same for each test. Start each sample with boiling water.
4. Place a tea bag in mugs 2–5.
5. Pour 200 mL of hot water into the liquid measuring cup. The measuring cup is used to obtain accurate volumes for each sample. The volume of the water should be the same for each test.
6. Pour the hot water from the measuring cup into mug #1. Mug #1 is a **negative control.** Controls are samples with known ingredients that should give clear results. They are used to test the procedure. In a negative control, there should be no "signal." Plain tap water is a suitable negative control in this experiment, because it has no tea.
7. Pour 200 mL of hot water into the measuring cup.
8. Pour the hot water from the measuring cup into mug #2.
9. Remove and discard the tea bag after 10 seconds. Use the stopwatch to keep track of the time.
10. Re-boil the water to keep the starting temperature constant. Pour 200 mL of hot water into the measuring cup.
11. Pour the hot water from the measuring cup into mug #3.
12. Remove and discard the tea bag after 30 seconds.
13. Pour 200 mL of hot water into the measuring cup.
14. Pour the hot water from the measuring cup into mug #4.
15. Remove and discard the tea bag after 90 seconds.
16. Re-boil the water to keep the starting temperature constant. Pour 200 mL of hot water into the measuring cup.
17. Pour the hot water from the measuring cup into mug #5.
18. Remove and discard the tea bag after 270 seconds (4 1/2 minutes).
19. Allow all of the teas to cool to room temperature.

Measuring the Strength of the Tea

1. To keep the light constant, block any sources of sunlight. Be careful not to let your shadow affect the readings.
2. Attach the wires from the multimeter to the wires of the photoresistor. For more information about using a multimeter, visit the Science Buddies page Electronics Primer: Using a Multimeter.
3. Turn the multimeter on. Make sure the multimeter is set to measure resistance, and that the leads are in the correct holes in the multimeter.
4. Tape the wires from the multimeter to the surface of the counter to keep them in place.
5. Label five other plastic cups 1–5.
6. Pour the water from mug #1 into the empty plastic cup #1.
7. Place the plastic cup with the water in it into the cup with the photoresistor.
8. Read the resistance of the photoresistor with the multimeter. Remember to record all data in your lab notebook. *Note:* You may need to experiment with the correct **range.**

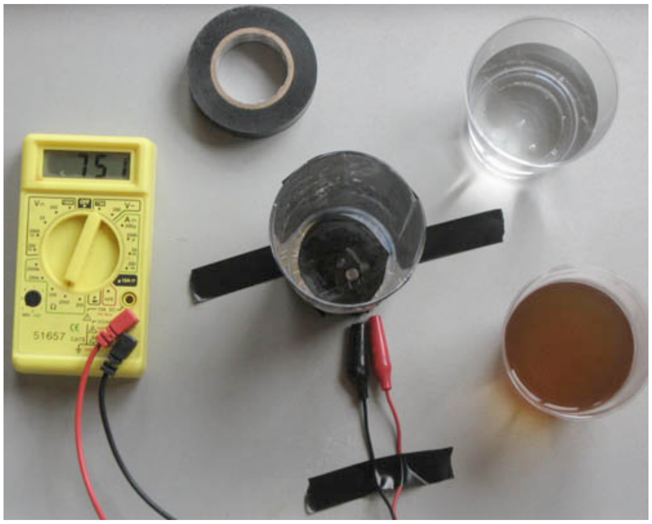

Figure 2. Experimental setup for measuring the strength of tea. The multimeter is set to read resistance. The cup in the middle has the photoresistor taped to the bottom. Two samples are shown on the right side of the figure.

9. Repeat the readings for cups 2–5.
10. To get duplicate readings, measure the resistance for each cup again.
11. Repeat *Making the Tea* and *Measuring the Strength of the Tea*, with clean and fresh materials, at least two more times. This ensures that your results are accurate and repeatable.

Analyzing Your Results

1. Make a data table with the resistance readings for each sample.
2. Calculate the average resistance for each brew time.
3. Subtract the value of the negative control (cup of water) from the other values.
4. Graph the average resistance, in ohms, on the y-axis vs. time (in seconds) on the x-axis.
5. Discuss the shape of the curve. Is it a straight line or does it curve?

Variations

- Try different temperatures of water to steep the tea. For example, 100°C, 50°C, 25°C, and 0°C, for 2 minutes.
- Use the photoresistor to measure the strength of coffee. For example, brew a small pot of coffee with one, two, three, or four scoops, keeping the volume of water constant.
- Use the curve you made of Resistance vs. Time to determine how long an "unknown" sample was brewed.
- Graph the log (base 10) of the Resistance vs. Time. What is the shape of this curve? See the entry in the Bibliography about Beer's law to learn more about how the concentration of a chemical is related to the amount of light absorption.
- Develop a test to determine what photoresistor readings correspond to the best-tasting tea.
- For more science project ideas in this area of science, see Cooking & Food Science Project Ideas.

Credits

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Last edit date: 2009-10-01 11:42:00

Career Focus

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